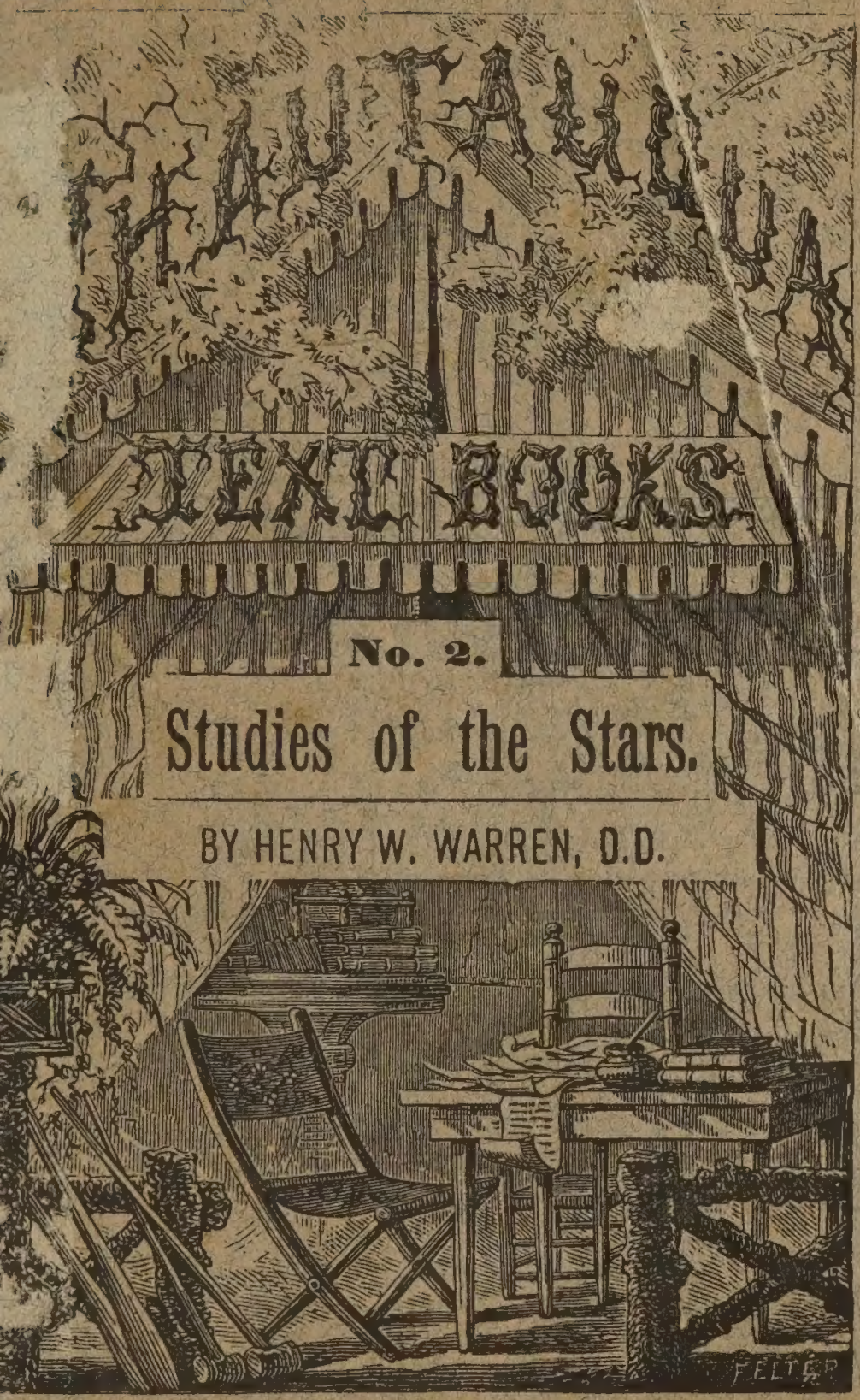


No. 2.

# Studies of the Stars.

BY HENRY W. WARREN, D.D.

Josie A. Stokes
Monroe
N. Y.

THE

# CHAUTAUQUA

# TEXT-BOOKS.



No. TWO.

# STUDIES OF THE STARS.

BY HENRY W. WARREN, D.D.



NEW YORK:
PHILLIPS & HUNT.
CINCINNATI:
WALDEN & STOWE.
1882.

# STUDIES OF THE STARS.

## THE MORNING STAR.

"The heavens number out the glory of the strong God."—DAVID.

The universe is God's name writ large. Thought goes up the shining suns as golden stairs and reads the consecutive syllables, all might, and wisdom, and beauty, and, if the heart be fine enough, and pure enough, it also reads every-where the mystic name of love. All God's flowers are rose-buds in language. And whether they are violets, or snow-flakes, or clustered suns filling immensity with their mingled hues, if held to the heart instead of the ear, they will speak in their own language the constant syllable, and power of love.

The stars speak the oldest language. The morning stars sing together. As the Psalmist says, "there is no speech nor language, their voice is not heard" by the

ear. Neither is the voice of the flowers. But how can the lover speak more gently, beautifully, or significantly, or how can the loved one hear more clearly, or feel more deeply? How can God write his name more widely or plainly, hold the open page before all men more constantly, or how can we read the message in more impressive language?

Some have asked whether the myriads of distant worlds were inhabited. It is not known. Perhaps it is a sufficient cause of their being that they should testify so effectually of God to every man, whether savage or sage, in all ages of time.

Let us learn to read the hieroglyphics, and then often turn to the blazonry of the page.

---

A million torches, lighted by thy hand
Wander unwearied through the blue abyss;
They own thy power, accomplish thy command,
All gay with life, all eloquent with bliss.
What shall we call them? Piles of glorious light,
A glorious company of golden streams,
Lamps of celestial ether burning bright,
Suns lighting systems by their joyous beams?
But thou to these art as the noon to night.

—DERZHAVIN.

# THE SUN.

"His countenance was as the sun shining in his strength."

**Diameter of Sun, 852,000 miles.**
**Revolves on its axis in 25 days.**

Let us cut ourselves loose from the world, from all worlds, and float as disembodied spirits at will. Behold! before us the Sun. How vast and seemingly infinite. When one has journeyed for weeks on the ocean, and seen no shore, the Earth has seemed vast. But if the Sun were tunneled through by a hole large enough to receive our world, and we had plenty of such globes to fill up the hole, how many should we use? Roll in a dozen, then 20, then 75 more. It takes 107½ earths side by side to measure the vast diameter of the Sun; 1,252,700 of our earths to make the vast extent of its bulk.

Its appearance of ever-during calm is delusive. Its vast atmosphere is traversed by storms. Tornadoes almost cease to mean any thing in such vast commotions. Our little seas and winds sometimes seem to raise tremendous tempests. One can

scarcely stand when the wind blows sixty miles an hour. But enlarge the world a million fold, put all its forces into proportional activity, and what then? The vast photosphere is often rent asunder in huge chasms, thousands of miles in extent. They close up again. The sides approach each other at the rate of 20,000 miles an hour. The advancing sides strike together. The rising wave of fire leaps thousands of miles in space. The blazing surge falls again into the incandescent sea, spaces larger than the whole conti nent of America are almost suddenly laid bare of light, and as suddenly overwhelmed. Vast spires of burning hydrogen flash out 80,000 miles into space. Professor Young on one occasion saw them projected over 200,000 miles from the surface. It is 300,000 times as hot as any summer we ever knew.

The movement of these spots can be easily illustrated. Take an apple, or any other sphere, pass an axis through it, then in the region of the equator cut various sized irregular spots, and darken them with ink. Incline the axis a little to the line of vision and cause your representa-

tive sun to revolve. Now observe when a spot comes in sight; it appears long, thin, and nearly perpendicular. As it comes to the middle the full breadth appears, but appears thin again as it passes to the farther side. Also, in consequence of the inclination of the axis, the line of the moving spots will curve upward ⌒ on one side, and ⌣ downward on the other. Sometimes as many as fifty spots have been seen at once, and sometimes the sun is wholly clear of them. The period of the wax and wane of these spots is eleven years, and corresponds with certain magnetic disturbances and auroral phenomena on the earth.

---

One Sun by day, by night ten thousand shine,
And light us deep into the Deity;
How boundless in magnificence and might!
O what a confluence of etherial fires,
From urns unnumbered down the steep of heaven
Streams to a point, and centers in my sight;
Nor tarries there; I feel it in my heart;
My heart at once it humbles and exalts,
Lays it in dust, and calls it to the skies.

—YOUNG.

# LIGHT.

## OUR INSTRUMENT OF INVESTIGATION.

"God said, Let there be light."

1. **Velocity of light, 191,000 miles per second.**

2. **It carries every-where indications of the material of the bodies from which it springs, and of the media through which it passes.**

3. **The intensity of illumination of objects at different distances is inversely as the square of the distances.**

1. Light goes the distance of the Earth's circumference in $\frac{1}{8}$ of a second. If we take a photograph by exposing the plate to the light $\frac{1}{20000}$ of a second, we have 9 miles of light to do the work. Light goes from the Sun to the Earth in 8 minutes; from the nearest fixed star in $3\frac{1}{2}$ years; from the polar star in 45 years; from more distant stars in thousands of years. They may have been smitten out of existence decades of centuries ago, but their poured out light is yet flooding the heavens. The wings of the morning bear swiftly to the

uttermost parts, but not beyond God's right hand's holding and leading.

Light is propagated in waves like sound. The air does not move forward, but the undulations send the sound on. Every least ray of light has all the seven colors, each being made by a different number of vibrations.

2. If we examine these colors by means of the spectroscope, we find vast numbers of microscopic parallel lines, some of which indicate salt, others iron, etc., in the bodies from which light springs, or in the media through which it passes. Suns differing from ours in the elements of their composition reveal it by their light. All these armies of light, from various suns, have a distinguishing uniform. The omniscient Eye seeing a light ray anywhere in the universe, though gone from its source a thousand years, and the very Sun from which it sprung blotted out of existence, is able to tell from which sun it originally came. Our Sun has nearly every substance known on the earth. We have discovered nine elements in Aldebaran; only three in Sirius.

3. If a lamp illuminates a page at the

distance of a foot with a brightness which we call 1, it will illuminate the same page at a distance of two feet, $\frac{1}{4}$ as much; four feet, $\frac{1}{16}$ as much. Neptune, our farthest planet, receives from the Sun only $\frac{1}{900}$ the light and heat on a like extent of surface the Earth receives. And, on the other hand, if two stars appear of equal brightness whose distances from us are as 1 to 4, the more distant star is sixteen times as bright as the nearer one. This affords a means of comparing the brightness, and probably the size, of suns whose distances we know. Thus Sirius is equal to 63 of our Suns; the Pole star, 83; Vega, 344; Capella, 430; Arcturus, 516; Alcyone, in the Pleiades, 12,000; a light that is unapproachable by mortals. Our Sun could not be seen at all at the distance of these bodies.

---

Study the light; attempt the high, seek out
The soul's bright path; and since the soul is fire
Of heat intelligential, turn it aye
To the all Fatherly source of Light.

—BAILEY.

# GRAVITATION.

1. **Attraction varies in direct proportion to the masses and,**
2. **Inversely as the square of the distance.**

There is a force which we call attraction or gravitation. It has certain modes of operation which we know, but of its essence we are profoundly ignorant. It acts with more than human intelligence, and with inconceivable constancy. It is as if every particle of matter had an attraction for every other particle of matter in the universe. It brings down the apple loosened from the bough, makes the avalanche thunder down the mountain, and holds all worlds together. That two bodies of the same mass, hanging freely in space, being attracted, should meet half way, is one phase of the first law; that two bodies whose mass is as 1 to 81, namely, the Earth and the Moon, being attracted together should meet $\frac{1}{81}$ of the distance from the larger, is another phase.

Since every particle of a world pulls its proportionate part, it follows, that if a

body is pulled an amount represented by 150 pounds on the earth, it would be pulled twice as much on a body of twice the mass. Hence an average man would weigh two pounds on the Moon and two tons on the Sun. Who could stand up, or even lie down, under the burden of his own body?

But if the Sun attracts so much, why are not all plucked off the Earth, and drawn to its blazing center? Because of the second law. The small Earth near attracts more than the great Sun far away. Streaming from a point, the influence which would cover a square foot a mile away, would cover four square feet two miles away. Hence the influence of the Sun on such little bodies as man is not appreciable at such a distance, but is appreciable on such a vast body as the Moon, or the sea, as will appear when we come to the subject of tides.

But why are not the Earth and all other bodies attracted to a common center in one universal crash and wreck? Because of another force that counterbalances gravitation, and holds all in delicate and perfect equipoise.

Suppose a rifle ball fired from A with force enough to carry it in one second 2,000 feet, to B. Gravity is a force sufficient to cause it to fall in the same second sixteen feet, to C. The result of both forces acting at once will cause the ball to take the curved line A, D. So the Earth has a forward motion, A, B, of 68,091 miles an hour. And the sun draws the earth toward it, A, C, $24\frac{402}{1000}$ miles an hour, giving the line A, D, which, being indefinitely


prolonged, circles back to its starting place, and so the Earth never flies off into space, nor falls into the Sun. When the slinger whirls the stone swiftly enough, it will fly off and crash the skull of Goliath; slowly enough, it will fall on his hand from above. The tension of the string represents attraction, the centripetal (center-seeking) force; the tendency to fly off in a tangent represents the centrifugal (center-fleeing) force. Now in all relations of

whirling worlds, these must perfectly balance each other, and that, not only in regard to two bodies, as Moon and Earth, but in regard to the Sun, all its planets, their moons, and myriads of suns besides. Nothing can be more wonderful. The infinite delicacy of the unstable equilibrium of the universe is inconceivable. The water of our globe is a good illustration. It rests in even poise around all shores. But if it were a trifle heavier or lighter, if the Earth should revolve slower or faster, if the Moon should come nearer or go farther away, if the Sun's attraction should increase or diminish, these plastic seas would rush, and bury either the poles or the equator miles deep, and leave the deserted parts miles from any moisture. Job could not understand the balancing of the clouds, much less the balancing of vast systems hung upon nothing. The Moon is another illustration. In going round the Earth it rushes 480,000 miles nearer the Sun. It feels the Sun's attraction increase with every mile. It is led thousands of miles out of its true course; but the elastic hold of the Earth at length prevails, and the Moon climbs away from

the Sun in defiance of its power. The Moon varies its distance from the Earth to the amount of 31,355 miles. The adjustment of two bodies and two forces in simple curve would be a comparatively easy matter. But there are over 60 causes of variation from such a simple curve in the case of the Moon. The value of each of these must be considered in calculating an eclipse, or the moon's place as a guide to the sailor. One planet affects every other. Jupiter's four moons affect him and themselves. They turned a comet out of its course in 1770, and tangled its path for four months. Still the equipoise is maintained. The scale nods from side to side, but neither pan ever kicks the beam.

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The universe is infinitely wide,
And conquering reason, if self-glorified,
Can nowhere move, uncrossed by some new wall
Or gulf of mystery, which thou alone,
Imaginative faith! canst overleap
In progress toward the fount of Love.

—WORDSWORTH.

# THE PLANETS.

"He hangeth the earth upon nothing."

| | Name. | Distance from Sun. | Time of Revolution. Yr. | Ds. | Diameter. | Hourly Motion. |
|---|---|---|---|---|---|---|
| 1 | Mercury .. | 35,392,000 | 0 | 88 | 3,058 | 95,000 |
| 2 | Venus .... | 66,134,000 | 0 | 225 | 7,510 | 75,000 |
| 3 | Earth .... | 92,430,000 | 1 | ... | 7,926 | 68,000 |
| 4 | Mars..... | 139,311,000 | 1 | 322 | 4,363 | 55,000 |
| 5 | Asteroids . | 200,000,000 | 3 | 230 | 240 | 44,000 |
| | | 315,000,000 | 4 | 225 | 2,000 | 41,000 |
| 6 | Jupiter ... | 475,692,000 | 11 | 317 | 84,843 | 30,000 |
| 7 | Saturn.... | 872,137,000 | 29 | 175 | 70,136 | 22,000 |
| 8 | Uranus ... | 1,753,869,000 | 84 | ... | 33,247 | 15,000 |
| 9 | Neptune .. | 2,745,998,000 | 164 | ... | 37,276 | 11,000 |

Looking out from the Earth, we see one body, the Moon, making a circuit about it in 27 days. Looking out from Jupiter, we see four bodies, or moons, making circuits about it at various distances, and in various times. Looking out from the Sun, we see 8 planets with satellites, making their various circuits about the Sun. The relative size and distances of the Sun and planets may be represented as follows: Put in position a globe 2 feet in diameter—a half of a barrel, or a two bushel basket will do; 1½ feet from its center mount on a stick, so as to reach the equator, a mustard-seed for the planet Mercury; a pea ditto, for Venus, 3 feet from the Sun's center; another pea, not all on the same side,

4 feet away, for Earth; a large pin-head, 6 feet distant, for Mars; 200 specks of pepper on a paper, 11 feet away, for the Asteroids; a small orange, 20 feet away, for Jupiter; a smaller orange, 37 feet away, for Saturn; a cherry, at 75 feet, for Uranus; and another, at 118 feet, for Neptune.

The speed of Mercury is 70 times as swift as a rifle ball that goes $\frac{3}{5}$ of a mile in a second. The great Earth flies more than 1,000 miles a minute, besides revolving its surface 1,000 miles an hour. Yet no bird is ever unnested or babe waked by the motion.

Neptune's motion is less than 200 miles a minute.

The planets do not go round the Sun in a circle, but in an ellipse, the Sun being in one of the foci. In consequence of this the Earth is 2,066,000 miles nearer the Sun in one part of its orbit than another, and Neptune is 50,384,000 miles nearer.

## MERCURY.

**Distance from Sun, 35,392,000 miles.**
**Diameter, 3,080 miles.**

Looking at the planets separately, little can be said of this one. He is so near the

Sun little can be seen of him. The average heat of this planet must be about 1½ that of boiling water, and for summer temperatures they must need thermometers ten feet long.

## VENUS.

**Distance from Sun, 66,134,000 miles.**
**Diameter, 7,510 miles.**

This brightest of all stars is never seen more than 47° behind the sun; then it is the Evening Star; or, before it, then it is the Morning Star. Venus has an atmosphere charged with aqueous vapor. She revolves on her axis in 23 hours, 21 minutes, 19 seconds. Seen from the Earth, it presents phases like the Moon, which will be readily understood by an inspection of

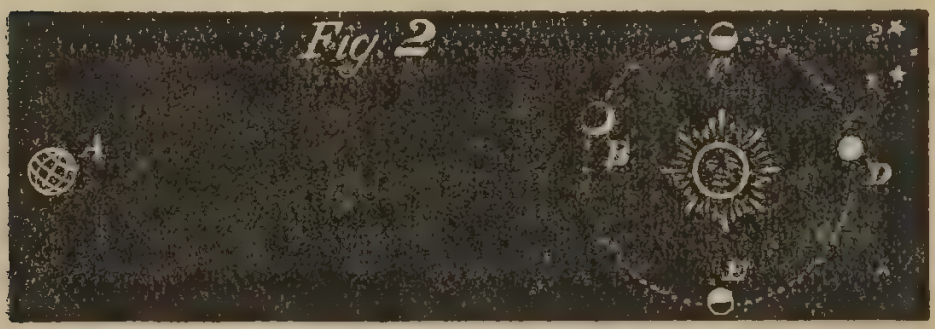



figure 2. When Venus is at B she would appear in the refiected light of the Sun as a thin crescent, as seen from A. When she is at C the lower half of its disk would

be illumined. When at D it would appear round as a full Moon. Her apparent retrograde motion is, also, easily understood. The motion of Venus is judged by the distant stars, among which it seems to be projected. When it is at B it appears among the stars at 1. Passing on to C, it seems to retrograde to 2. Going to D, it passes back to 1 again. The retrograde movements of the exterior planets are much greater, and as easily understood.

## THE EARTH.

**Distance from Sun, 91,430,000 miles.**
**Diameter, Polar, 7,898 miles.**
**" Equatorial, 7,924 miles.**
**Mass, 6,000,000,000,000,000,000,000 tons.**

More can be shown by illustrations that the reader can produce than by any drawing. Put on the table or wall a lamp shade, or other globe, to represent the Sun, mark on it the spots, and incline its axis $7\frac{1}{2}°$ from the perpendicular. Around this, as one focus, draw several elliptical orbits, at suitable distances, for as many planets as you can represent. Now take an apple or other ball, flattened at the ends; through these pass an axis

sharp enough to stick into any part of the orbit drawn, and long enough to raise the ball as high as the center of the Sun. Draw the equator midway between the


poles, and add meridians of longitude and parallels of latitude if you choose. Stick in pins for men, heads up, and sticks for a winter forest; set up the Earth on its long axis in some part of the orbit, inclined from the perpendicular 23½°. Many things will now become evident; *e. g.*, by revolving the Earth on its axis, the morning sunlight will come over the east, then shine from above, and then set in the west. Also the Moon and the dome filled with stars will seem to revolve in like manner. Since men are attracted to the earth, it makes no difference whether their heads are up or down; indeed, toward the Earth is always down to them. Hang the Moon from the upper pole so that it will swing

round the earth near the equator, and it will be seen that when it comes between the Earth and the Sun it eclipses that orb, and when it goes behind the Earth into its shadow it is eclipsed itself. Also, when the Moon is nearly between the Earth and Sun it shows only a thin crescent of illumination. When it has passed 90°, or ¼ of a revolution, it would be half illumined; and when opposite the Sun, and not in the Earth's shadow, it shows full Moon. It is seen, also, that the sunlight reaches 23½° beyond the lower pole, and makes that region perpetual day as the Earth revolves. And 23½° about the upper pole is in constant night. Remembering that the Earth's axis always points to the same north star, *i. e.*, it does not revolve in two directions at once, carry the Earth to the other side of the Sun. Now the upper pole is illuminated, making the days long and nights short below the 23½°, and leaving the lower pole dark.

The measurement of the earth is easy. We observe that the North Star is 40° above the horizon at Philadelphia. We go north till it is 41° above, and find we have gone 69 miles, which, multiplied by 360°,

gives the circumference, 24,887 miles. The length of the degree differs a little in different places, according to the oblateness of the spheroid in those places.

The distance of the Sun is measured in several ways: by taking the angles he makes at the two ends of a horizontal line as long as the Earth's semi-diameter; by the transit of Venus; by the velocity of light; and, knowing the Sun's diameter, measuring his distance by the apparent breadth of the disk.

Two lines drawn up from each end of a line 10 inches in length, and perpendicular thereto, will make right angles with that line, be parallel, and, of course, never meet. But if drawn so as to meet anywhere within three hundred miles from that 10 inch base line, such is the wonderful perfectness of astronomical instruments that they would measure how much these angles varied from right angles, and know the distance at which they met. Now, to measure the distance of the Sun we could take two stations with the Earth's diameter between them, if necessary.

Measurement by the transit of Venus is more exact. The instant when that

planet touched the edge of the Sun would appear very different to observers on opposite sides of the Earth, and knowing the distance of Venus from the Earth, the solution of the problem becomes easy.

We are far from the Sun. Call it in round numbers 92,000,000 of miles. If we lay an imaginary track thither, and put on an imaginary locomotive running at the usual express speed, it would take 8 months to reach the orbit of the Moon. Put a little babe on that train bound to the Sun. He grows up, passes the period of his glad youth, strong manhood, arrives at the end of his 70 years, the allotted time of man, but his dying eyes look vainly for a near view of the goal of his life's journey. Then let another babe take his place. Childhood, youth, manhood, age—another life goes by. Not arrived. Add another life, 70 years more. Not arrived. Add a fourth period of life, then a fifth, and when all five have lived their lives and died, after 350 years of travel, that locomotive that has never stopped a minute, day nor night, for wood, water, or to cool its glowing axles, would barely get that last man there in time to bury him.

Hardly any thing is quicker than the flash of the sensation of pain. But if a man had an arm long enough to reach the Sun, it would be 135 years before he knew he was burned

## THE MOON.

**Mean distance from Earth, 238,818 miles.**
**Diameter, 2,159 miles.**
**Revolution about the Earth, 27 + days.**
**Revolution on axis, same time.**

The Moon is our next-door neighbor. If you notice a star in proximity to it, you will see that the distance is very perceptibly different in an hour. On the next evening the Moon will be 13° farther east. This gives an entire revolution from west to east in 27 days. By revolving on its own axis in the same time it manages to show us always the same face. No man ever saw the back side of the Moon. It is a craggy, desolate, upheaved, torn, rent, mountained, chasmed, volcanoed, and moon-quaked orb. The gravity is so small —0·16 that of Earth—that precipices do not tumble down, pits do not fill up. They can be seen in the southern part 3 miles deep, of all sizes from $\frac{1}{4}$ of a mile to 10 miles across. This little orb, $\frac{1}{80}$ the size

of Earth, has 28 mountains higher than the "monarch of mountains," Mount Blanc. Its highest mountain, Doerfel, is 24,945 feet high.

The Earth, seen from the Moon, looks like the Moon seen from the Earth, only 13 times as large. It is sometimes between the Moon and the Sun, and sometimes opposite the sun. But as the Moon always presents the same side to the Earth, Earth seems stationary over that point. The Moon has no water or atmosphere; if it ever had, they are absorbed in the interior of the burned out char.

The path of the Moon around the Earth is indescribable. Mount an 8 inch ball on one end of a 20 foot pole, and a 2 inch ball on the other, and they just represent the Earth and the Moon, and their distance apart; find the center of gravity, mount it on a pivot, and set it whirling. The center of the Earth revolves from this cause alone on an orbit 6,000 miles in diameter, and the Moon in one 476,636 miles in diameter. Carry the whole apparatus forward 1,000 miles a minute around the Sun, and the Moon's path is a set of curves impossible to describe.

ECLIPSES.—If a plane be imagined in which the line of the Earth's orbit around the Sun lies, that is called the plane of the Earth's orbit, or the ecliptic. Of course it passes through the centers of the Sun and the Earth. A like plane of the Moon's orbit passes the center of the Moon and the Earth. Now, if these corresponded, or were one and the same plane, the Sun would be hidden or eclipsed every time the Moon passed before the Earth, and the Moon eclipsed every time it passed behind the Earth. But these planes do not correspond. That of the Moon is inclined to the other, passing through it, one half above and one half below. If the Moon


should be at *a* when the Earth was in that part of its orbit, and the intersection of the planes of the orbits in that position, the Sun must be eclipsed. But if the Earth was at *b*—the intersection of the

planes remaining the same—and the Moon came between it and the Sun, the Moon would be so far below the connecting line as not to hide the Sun. At some intermediate point it might come so near the line of intersection as to partially hide the Sun. Eclipses are greater or less in degree, according to the varying distance of the Earth from the Sun, the Moon from the Earth, and by being in different parts of their orbits.

TIDES.—The attraction of the Moon for the nearer and farther sides of the Earth varies inversely as the square of the distance. It attracts the near side much more than the far side. The mobile air and water yield to this attraction more than the more distant mass of solid Earth, and pile up a tide under the Moon. And the solid Earth yields to this attraction more than the far-off air and water of the other side; and hence the Earth, being solid, is pulled away from the mobile air and water of the other side, leaving it piled up on the side of the Earth opposite to the Moon. When the Sun and Moon join their forces in the same line, we have tides one third higher than the Moon's,

called spring tides. When they exert their forces at right angles with each other the Sun subtracts one third from the Moon's tides, giving what are called low or neap tides. Bodies of water so small as the great lakes or the Mediterranean Sea are too small to show a perceptible tide. Tides are so much affected by currents, islands, trend of shores, distance of Sun and Moon, etc., as to give great variety of tides; those of the Bay of Fundy being 70 feet, Boston 11 feet, New York 5 feet, etc.

The Moon has been getting nearer to the Earth for thousands of years. Will there be a collision between these sailers of the sky? Is a ball large enough to wreck a continent, going at 40 miles a minute, about to meet us going a thousand? Never fear. It approaches slowly. It has shortened its time of revolution only 10 seconds in a century; and after approaching the Earth for millions of years, will begin to recede again by the same power that drew it nigh. What stupendous prophecies human science enables us to make! Shall any prophecy be too difficult for Divine science or Omniscience to declare?

## MARS.

**Distance from Sun, 139,000,000 miles.**
**Diameter, 4,400 miles.**
**Daily revolution, 24 hours 37 minutes.**

This planet is singularly like the Earth in length of days, variety of seasons, abundant vapor for rain, ice around the pole, which melts as the Sun approaches, and in divided land and water.

We enjoy greatly differing opportunities for acquaintance. When we are on opposite sides of the Sun we are 230,000,000 of miles apart. When on the same side we may be quite near. If Mars is in that part of his orbit called perihelion, or nearest the Sun, and we at aphelion of our orbit, or farthest from the Sun, we may be only 33,000,000 of miles apart. This favorable opportunity happens about once in 79 years. In this year of grace 1877, Mars introduced us to two members of his family we had never seen before. Mr. Hall, of the Washington Observatory, discovered in the month of August two moons, one having as a period of revolution 30 hours 14 minutes, and the other 7 hours 35 minutes. In consequence of this time of revolution being less than

Mars' axial revolution, this Moon rises in the west and sets in the east. Probably neither of them is 10 miles in diameter.

## ASTEROIDS.

The law of the distance of the several planets from the Sun is expressed by this series:—

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 3 | 6 | 12 | 24 | 48 | 96 | 192 |
| Add | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | 4 | 7 | 10 | 16 | 28 | 52 | 100 | 196 |

Now this lower line of figures nearly represents the relative distances of the planets. It approximates the truth to say that each one is twice as far from the Sun as the next interior one. Thus it was seen that there was a strange gap between Mars and Jupiter, and twenty-four astronomers made a league to search for the missing planet. Piazzi discovered a small star January 1, 1801, which, despite his long sickness and the loss of the planet in the Sun's rays, was rediscovered by Olbers on December 3, 1801, and named Ceres. This proved to be but the herald of a large body of small planets, of which nearly 200 have now been discovered, having distances from the Sun varying

from 200 to 315 millions of miles. The combined mass of all these asteroids is not probably one tenth of that of the Earth.

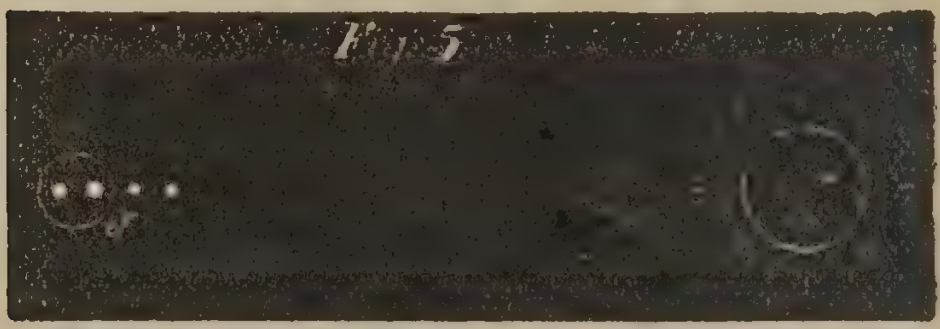
What a proof of the accuracy of astronomical observations of movements, when each of these nearly 200 bodies, which cannot be distinguished from each other by any appearance they present, can be accurately known, even though not seen for 50 years, by the observation of their line of motion!

## JUPITER.

**Distance from Sun, 475,692,000 miles.**
**Diameter, 85,000 miles.**
**Daily rotation, 9 hours 55 minutes.**

Behold the monster of planets! All the rest put together would barely equal two fifths of this. It is 300 times the mass of the Earth, and 1,233 times the volume. It is royally attended by four moons. The inner one makes a revolution in 42 hours, (instead of 27 days, as our Moon,) and the outer one in 16 days 16 hours. Eclipses are not only an every-day matter, but almost hourly. These eclipses have done excellent service in measuring the velocity of light. We know to a second when they take place. But when the Earth is on the

opposite side of the Sun from Jupiter these eclipses take place 16 minutes later than when on the same side as in figure 5.




Is celestial chronometry getting deranged? No! these great worlds swing, never a second out of time, nor an inch out of place. By going to the other side of the Sun we become 184,000,000 of miles farther from Jupiter, and the light that brings us the intelligence consumes the extra time in passing over the extra distance. 184,000,000 miles÷960 seconds= 191,000+miles per second as the velocity of light.

I have seen the rude little telescope with which Galileo discovered these moons. A better one can be bought for five dollars.

There is probably no resemblance between the condition of Jupiter and the Earth. The body is probably intensely heated and feebly self-luminous. It has no variety of season. It presents to the

view of the telescope changing lines of belts and spots from which little can be trustworthily inferred. In consequence of its extreme rapidity of rotation the flattening of its poles is very great. The equatorial diameter exceeds the polar by more than 6,000 miles.

## SATURN.

**Distance from Sun, 872,137,000 miles.**
**Diameter, polar, 66,500 miles.**
**Diameter, equatorial, 73,500 miles.**
**Axial revolution, 10 hours 30 minutes.**

This is the most wonderful planet of all. It is the largest, except Jupiter. Its mass is three times the mass of all the other planets combined, Jupiter being omitted. It is 90 times the mass of the Earth, and 700 times the volume. It differs from all other known celestial bodies in having enormous rings. It presents these at different inclinations to the Earth. They appeared to Galileo, who first saw them, as two small bodies on either side of the planet. Subsequently they presented only the thin invisible edge to his sight and disappeared altogether. Again they appear as in figure 6.

They lie in the plane of the planet's equa-

tor, and revolve with it. The outer one is less brilliant, and inside of them both is a dusky semi-transparent ring, seen with difficulty. The inner edge of this ring is constantly approaching the planet, while the breadth of the two outer, or bright rings, is constantly expanding. These


rings are supposed to be composed of myriads of independent minute satellites mingled with vapor. Hence not solid.

Saturn has a system of eight moons, some of enormous size and revolving at a great distance.

## URANUS.

**Distance from Sun, 1,753,869,000 miles.**
**Diameter, 33,000 miles.**

The distance of this planet from the Sun is 19 times that of the earth. A train started from the sun thither 6,000 years ago would be only just arriving.

This planet has four moons, which pre-

sent the wholly anomalous phenomenon of revolving nearly over the poles and in a retrograde direction.

## NEPTUNE.

**Distance from Sun, 2,745,998,000 miles.**
**Diameter, 35,000 miles.**

The orbit of Uranus had embarrassed astronomers for years with irregularities which could not be accounted for. Bouvard suggested another exterior planet. Leverrier of France, and Adams of England, undertook to tell where it must be from these irregularities. Both succeeded perfectly in determining the mass, orbit, and actual position of an unseen body.

On searching in the place indicated, the planet was discovered first at Berlin, and afterward at Cambridge, England. It has one satellite. Probably two. The cold here, unless these outer planets have heat of their own, or an absorptive and retentive atmosphere, must be 100° below zero, and the far-off sun looks but little larger than a first class star. We thus reach the outer boundary of the solar system, but have scarcely taken the first steps of a voyage to the surrounding stars. Light

goes to Neptune in four hours, to the nearest fixed star in 3½ years.

The order of the planets—Mercury, Venus, Earth, Mars, Asteroids, Jupiter, Saturn, Uranus, Neptune—may be remembered mnemonically thus:—Mercury V*iews* Earth; Mars A*nd* Jupiter *the* SUN. Or the initials give us a name with French and English titles, as:—M. Ve Maj. Sun.

The number of satellites may be remembered by this series, beginning with Earth, 1, 2, 4, 8, 4, 2.

---

Who rounded in his palm these spacious orbs,
And bowled them flaming through the dark profound,
Numerous as glittering gems of morning dew,
Or sparks from populous cities in a blaze,
And set the bosom of old night on fire?

—YOUNG.

# COMETS.

"Wandering stars, to whom is reserved the blackness of darkness forever."—JUDE.

Notwithstanding our king of day may make Neptune his farthest province, he sends his scouts much farther.

When the comet of 1680 wheeled round the Sun, 200 years ago, it commenced an outward march of 4,500 years before it should "about face" and begin its equally long return. It seems as if its long "blackness of darkness" were best expressed by the term forever. Some go so far that gravitation turns the other way; other suns allure them, and they go as envoys to other systems of worlds than ours.

The orbits of these strange visitors are extremely elliptical, circles whose two sides have been well-nigh brought together. They come rushing down into the steady, well-ordered ranks of planetary bodies from all points of the sky, above, below, around. They are like dashing aids-de-camp among the ordered lines of battle. Their speed is sometimes frightful. The comet of 1680, above referred to, went, when nearest the Sun, 1,000,000 miles an

hour. It went within 130,000 miles of the Sun, and must have been heated 2,000 times hotter than red hot iron; others wheel outside of Neptune's orbit, and are never light or warm; 700 have been seen by the naked eye since the time of Christ. The number that belongs to our Sun is supposed to be several millions. They may have tails 200 millions of miles long, like the comet of 1843, or no tail at all, like that of 1585; or the same comet may be in both of these conditions at different times.

They are not specially dense bodies, for small stars have, at times, been seen through their brightest parts. Biela's comet was once famous for the regularity of its return, having a period of 6¾ years. In 1847 it divided into two comets under our eyes. It was seen in 1852, the parts separated by a distance of 1,250,000 miles. It was not seen in 1866 and 1872, but the brilliant shower of meteors in November 27, 1872, was, doubtless, occasioned by some of the remains of that comet. When that shower of streaming light flashed in our upper air, Klinkerfues, a German astronomer, telegraphed to Madras, on the

other side of the globe, "*Biela touched earth on 27th. Search near Theta Centauri.*" And searching there the observer saw the departing comet, through some part of which the Earth had passed.

Comets are probably composed of disconnected meteoric bodies traveling together, with so little coherence that the Sun lengthens the mass into a stream as it approaches him. Their mass is so inconsiderable that Halley's comet, due in 1759, was retarded by Jupiter 618 days without any appreciable effect on that body.

Science has scattered one cause of fear since 1456, when a brilliant comet, curved like a Turkish cimeter hanging in the sky, caused all Europe to pray, "Good Lord, deliver us from the devil, the comet, and the Turk." Pope Calixtus III. excommunicated this comet, whereupon it went away. Nevertheless it gets courage to come back every 75 years.

# METEORIC SYSTEMS.

**"The Lord cast down great stones from heaven upon them unto Azekah, and they died."—JOSHUA.**

Looking into the clear heavens almost any night we may see a bright light suddenly appear, dart a few degrees across our vision, and as suddenly disappear, or burst into detonations and coruscations, and pelt the Earth with stones of various sizes, from very small to 30,000 pounds weight. In November, 1831, 1832, and 1833, three successive showers covered an area of 1,000 miles long by 500 miles wide. A man counted 650 in fifteen minutes. The shower lasted seven hours, and 273,000 might have been seen from a single point. The cause of this display is the darting of stones of various sizes, at great velocities, into our atmosphere. Their force is turned to heat, the air and themselves set on fire; and they either pass out of the air, cool off, and disappear, or dissipate in the fervent heat, or burst and descend as solids to the Earth. Over 2,000 were collected from a small area in Normandy in 1803, the result of a single shower.

These innumerable bodies seem to

flow in streams, like motes in a sunbeam, in regular orbits. Leverrier, whose spirit passes into the upper heavens as I write these pages, computed that the period of the meteor stream of 1831, 1832, and 1833, was 33¼ years; but the stream that flowed along the orbit was so long that the earth went through it for three successive years. Some of the streams may flow over the entire length of the whole orbit. The position and direction of over 100 of these meteor streams is already known. Others are liable to be added to our system from surrounding space at any time by the attractive power of the Sun or distant planet. Thus comets or meteor systems seem closely related. Where the separate bodies are near enough to be visible in the sunlight they are called comets. Thus their tails can expand, contract, or disappear; or even the whole body be so extended as to become invisible.

# THE FIXED STARS.

**"Is not God in the height of heaven? and behold the height of the stars, how high they are!"**

In a clear night the heavens seem like a vast dome studded with stars. They appear to rise in the east, and sweep like a mighty army, perfectly disciplined, toward the west. If each left its line of march, marked by a tracery of golden fire, we should have a dome of parallel lines in perfect circles. All these would be concentric near the north polar star. And if we should go south of the equator new stars would appear circling in another dome, and all concentric at the south pole. All these stars seem to be at the same distance. If we take our telescopes, that detect a convergence of 10 inches in 300 miles, and from opposites of the Earth point two of them at the same star at the same instant, they both make the same angle; the lines do not converge. Then we observe a star at a given date, and wait 6 months till the world has whirled across its orbit, and the base line is not 10 inches nor 8,000 miles, but 184,000,000. Then we observe the star again, but it is

the same angle still. That is, the Earth's orbit, 184,000,000 of miles wide, seen from a star would appear a point. But hold! we discover that there are a few stars that appear to show signs of parallax, *i. e.*, showing different angles from the two sides of our orbit. Suppose we measure the inclination of these telescopes on a mural circle 30 feet in circumference. We divide every circle into 360 degrees, each degree into 60 minutes, every minute into 60 seconds, in all 1,296,000 divisions of the circle by seconds. Each of these will measure on a 30 foot circle ·00027 of an inch. Of course they can be read only by a microscope. But the greatest parallax of any star yet discovered is that of a *centauri*, which is only 0″·9, one tenth less than one second. This gives a distance of 20,000,000,000,000 of miles, or a light journey of 3¼ years. The nearest star in our northern hemisphere is 61 *cygni*, which has a parallax of 0″·55, which gives a distance of 61,000,000,000,000 miles, a journey for light of 7¼ years. Sirius, with a parallax of 0″·15, is twice as far. The mind of man is as incompetent as a babe to appreciate these distances. No tele-

scope ever enlarges a star from a mere point to a disk.

DOUBLE STARS.—When a telescope of high power is applied to some stars they divide into two; as two lights which far off appear as one, may be discerned to be two on nearer approach. This might happen if two stars were in the same line of vision, and had no relation to each other. They are called double stars when they are related together and revolve about a common center of gravity. The Pole Star is double; Sirius also. The second one, in the tail of the Great Bear, Mizar by name, is also double. The eye sees Alcor very near Mizar, but that is not its companion. Every one knows the Great Dipper, the end stars pointing very near the North Star. Imagine a line drawn from the Pole Star to the star Megres connecting the handle and dipper. It will be 36° long. At the Pole Star erect a perpendicular to this line 52° long, and you come to Vega, one of the brightest stars. 2° from it—the Pointers being 5° apart—and 2° from each other, will be seen two faint stars making, with Vega, a triangle nearly equilateral. The northern star can be seen

double with an opera-glass. With a first-class telescope it appears quadruple. There are over 6,000 of these double stars already discovered. It is not good even for stars to be alone.

Our law of attraction tells us that two suns near each other in fact—not merely in line of vision—must be attracted together unless attraction is counterbalanced by revolution about a common center. Eagerly we watch to see whether they revolve or rush to ruin. Yes, truly, they are seen in revolution. One pair in the left hind paw of the Great Bear has made an entire revolution since it was observed. Its time is 60 years. The set called Mizar has a period of 200,000 years. Of the quadruple star we found near Vega, one pair revolves in about 4,000 years, the other pair in about 12,000 years, and the two pairs whirl about their common center of gravity in about a million. Add to these suns, planets, satellites, comets, and meteors, and complexities result that no mind but the Infinite can pierce.

All observers have noticed that stars differ in color. About one half are white, giving all the colors of the *spectrum;* ½ are

yellow. About 100 are red, and a few of a blue tint. It is probable that all variations from white result from the presence of absorptive vapors cutting off certain colors. The two members of double stars always differ in color. One is orange, the other green; one is yellow, and the other a sapphire blue, etc. A planet revolving between them may have a rosy day, followed by a purple twilight, and a night of sapphire blue. Earth is full of variety. The same Creator flashes such life along the starry arteries that the silent spaces respond in blushes of rosy light, and changeful scenes of varying beauty.

VARIABLE STARS.—Draw a line from the Pole Star to the Pleiades, stop 25° before reaching them, and to the west curve four faint stars and one bright one in Perseus. 15° degrees east blazes Capella, with the little triangle of the kids just below. Follow down the line from the pole about 6° farther, turn to the west the same distance. There is Algol. For 2½ days it is almost as bright as any star. Then in 3½ hours it fades away and is lost to sight. Then in 3½ hours regains

its former brightness. It throbs like a pulse of light, seems like a living eye flashing and growing dim.

Draw a line from Capella through the Pleiades, and continue it as much farther, and you will come near Mira, the Wonderful. For half a month it is almost as bright as any star; then for three months it fades away, is lost from sight entirely. But after 5 months its resurrection morning comes, and in three months again—a year in all—our Wonderful is in its full glory in the heavens. The star Megres has been losing its brightness for a century. Our own Sun is a variable star having a period of 11 years.

TRANSIENT STARS.—During the past century 10 new stars have appeared. Whether the work of new creations, or the reappearance of some star lost before our time, we cannot tell. During the same period 13 stars have disappeared. Some seemed to be on fire, as if they and their attendant worlds were consumed with fervent heat.

These little systems have their day;
They have their day and cease to be:
They are but broken lights of Thee,
And thou, O Lord! art more than they
—TENNYSON.

# THE SUN'S MOTION IN SPACE.

"His going forth is from the end of the heaven, and his circuit unto the end of it."—DAVID.

The Sun does not rest quiet in space it has a going. And as all celestial motion must be circuitous to safety, or rectilinear to ruin, the Sun has a circuit and safety. The Earth and the Moon go forward as they revolve. The Sun, with all its moving planets, asteroids, satellites, and streams of cometary matter, moves on from one end of heaven to the other. About 17° ahead of Vega may be seen an irregular quadrangle of stars, some 10° long north and south, 7° on the north end and 4° on the south end. The stars of this region seem to be getting farther apart by reason of the solar system approaching at the rate of 8 miles a second. The stars at the opposite point of the dome seem drawing together, like the rails behind a flying train.

Other suns are also in motion. In 36,000 years the handle of the Great Dipper will be broken to a right angle at Mizar, and Dubhe will have fallen from

the opposite end, making the seven stars into the form of a gigantic S.

But where is the Sun that sways suns, as the Earth does the Moon? Mädler of Dorpat announces that the star Alcyone, one of the Pleiades, is the central sun of our Sun, and many others. The Royal Astronomer of England does not regard this as proved; but still it is very probable. It gives our Sun and its worlds an orbit of 20,000,000 of years. The vast machine, with flaming suns as rolling wheels, is not likely to vanish just yet. The time of a single trial revolution is incomprehensible to man. When God was testing Job's wisdom and strength, he asked him if he could bind the sweet influence of the Pleiades. Job did not know they had any influence. But when we come to see that they bind the universe together, and float innumerable great worlds as easily as the wind floats bubbles, that they reach over a distance that it takes their light 700 years to travel and control the movements of all worlds with infinite exactness, then we see that the question is not merely an expression of infinite power, but of infinite wisdom as well.

# NAMES AND POSITIONS OF THE STARS.

"Tell the stars, if *thou* be able to number them."

"He telleth the number of the stars; he calleth them all by their names."

It is worthy of much pains to learn the names and places of the stars. We shall be uttering some of the same sounds by which God calls their names. They will seem like familiar friends, and will shine lovingly upon us when thousands of miles from other friends and from the earth. Of the uncountable millions let us learn a few. Beginning at the end of the handle of the Great Dipper, we have in order Benetnasch, Mizar, Alioth, Megrez,—the junction,—Dubhe, Merak—last two, "the pointers," 5° apart—and Phad. 18° forward of Dubhe is the Bear's Nose, and three pairs of stars, 15° apart, below, show the position of three feet. Follow the Pointers 30°, you see Cynosura, or the Pole Star. 4 stars besides it make the curved up handle of the Little Dipper, in Ursa Minor.

Between the Two Bears, 13° from Megrez and 11° from Mizar, are two

stars of the tail of the Dragon. Follow a curve of 15 stars, doubling back, to a quadrangle 5° to 3° on a side, 35° from the pole, for his head. Tongue runs out to a star, 4° in front.

From Megrez, through Cynosura, and as much farther, you see five stars as an irregular *w*, which is Cassiopeia. 32° farther is Alpherat, in the square of Pegasus. Sides, 13° to 16° long. Pass the diagonal star and there are two stars, 8° and 9° for the neck of the horse, and one at right angles, 6° west, for the nose. Alpherat is also the head of Andromeda. Nearly diagonally to the square are three stars in line from Alpherat, 7°, 14°, and 26°. The first one, and a star on each side, are in the breast; the second, and two at the west, are in the belt. Just above the third is a nebula, barely visible to the naked eye. The third is in the foot. 10° farther in the same line is the segment of Perseus; and $\frac{2}{3}$ of the distance between, and 8° east, is Algol again.

The Pleiades fix the shoulder of Taurus; the Hyades, shaped like a V, with Aldebaran burning on the eastern point, his nose and eyes. Follow the lines of the

V 16° further. Two stars 7° apart, nearly in line between Capella and Betelguese, mark the tips of his horns. From the Pleiades, through Aldebaran, and 15° farther, is Bellatrix, 2d mag., in the left shoulder of Orion; Betelguese, 1st mag., is 7½° east. 26° E. of this is Procyon, in the Little Dog; and 26° S. of this, making an equilateral triangle with Betelguese, is Sirius, in Canis Major. 16° east of Procyon are the seven stars of Hydra in a compact cluster, the four brightest being a trapezium. South of Bellatrix are the bands of Orion, and bright Rigel in his upraised foot. At the lower foot is the irregular quadrilateral, 3° by 5½°, of the Hare.

Betelguese to 2° S. of Aldebaran 21°, then 35° farther are three stars in the head of Aries. From Procyon, 24° toward the Pole, are Castor and Pollux, second magnitude, 5½° apart. From Megrez to Pole, 36°, then perpendicularly to that line 52°, is Vega, already known. 16° south-east, passing at 9° the circular nebula, is Albireo, in the bill of the Swan. Lying north-east thence are tne six stars of the Swan, making quite a perfect cross, 20° long by

17° wide. The second star from the foot is variable. 20° east by south of Albireo, 34° from Vega, is Altair, in the Eagle, the middle star of three in a line 6° long.

Observe the double curve of five stars 17° long. south from Altair. That runs through Antinous. 11° north-east from Altair is the diamond form of the Dolphin.

From the Pole pass Vega, and 65° beyond is Sagittarius, the little Milk Dipper on his breast, his bent bow 9° to the west. From the Pole by the star in the tongue of the Dragon 37°, thence 14°, almost touching the trapezium in the loins of Hercules, then 24° farther, 75° from the Pole, we see two second magnitude stars, 5° apart, which are in the heads of Hercules and the Serpent Bearer. 38° farther and we find two faint stars in the Serpent Bearer's foot, 15° east of Antares, which is 32° west of the Milk Dipper, and in the magnificent constellation of Scorpio. 20° west is the square, 6° by 9°, of Libra.

From the Pole by Mizar 35°, then 35° more and Arcturus is 14° east, then 40° farther is Spica, first magnitude, in Virgo.

From the Pole by Megrez and 30° farther is the bunch of Berenices' hair. From the Pole through the middle pair for the Great Bear's feet, and 30° farther, is Regulus, in the shoulder of Leo. It makes the end of the handle of the sickle that curves to his nose. Nearly half way to Arcturus, and 2° out of line, is Denebola in the lion's tail. It makes an equilateral triangle with Spica and Arcturus.

In touching these few points we pass innumerable evidences of that motion that makes the heavens alive, pass double and variable stars by the thousand, and nebulæ made of countless suns, till we exclaim with Job: "Lo, these are but parts of his ways; a mere whisper is heard of him. Who can understand the thunder of his power, who by his Spirit garnished the heavens?"

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The innumerable stars
Shining in order, like a living hymn
Written in light.

—WILLIS.

# TEST QUESTIONS.

What is the Sun's diam.? time of axial revolution? How many Earths equal his bulk? mass? What of the size, appearance, and periodicity of the Sun's spots?

Give the velocity of light. Illustrate it. What two laws are stated? Illustrate each. How are the constituent elements of a light-giving body discovered?

What two laws of gravitation? Why would a man weigh two lbs. on the Moon and two tons on the Sun?

Explain the cause of the curvilinear motion of the Earth. Illustrate the delicate balancing of worlds.

Give names of planets in order. Distance from Sun, and other facts in the table, at least of the Earth. What would be the relative size, and distance, of the planets, if the Sun be represented by a globe two feet in diam.?

What of the heat of Mercury? velocity?

Explain the apparent retrograde motion of interior and exterior planets.

How is the Earth's circumference measured? How long would it take a locomotive to run to the Sun?

Describe the Moon's orbit. Surface. Mountains. Why is not the Sun eclipsed at every new Moon? What are the causes of the tides? of their variation?

What caused men to hunt for the Asteroids?

What is Jupiter's relative size? Why is he so oblate? How is velocity of light measured by Jupiter's moons?

What is the comparative volume of Saturn? What of facts concerning his rings?

What anomalous fact concerning Uranus's moons?

What led Leverrier and Adams to seek for Neptune? What of the light and temperature of Neptune?

Give six facts of comets. The history of Biela's comet. Of what are they probably composed?

What are meteors? Of how many meteor systems have we defined the position?

How is the distance of fixed stars determined? What ones do you know the distance of?

How many double stars can you name? How many can you point out in the sky? What is the period of their revolution? What of the color of stars?

What of the variable star Algol? Mira? How many stars have appeared in a century? disappeared?

What is the proof of the Sun's motion? What is its period? velocity?

There are given here the positions and names of 25 stars and 30 constellations. How many can you show your friends?

# STUDENT'S OUTLINE.

## THE SUN.

1. Diam. 2. Revolu.
3. Comp. Earth. 4. Activ.
5. Hydro. 6. Spots.
7 Motion of.

## LIGHT.

1. Veloc. Illus. *a*. ⅛ sec.
*b*. photo. *c*. fr. stars.
*d*. waves.
2. Sig. material. *a*. salt, iron, etc., in sun.
*b*. Alde. *c*. Sirius.
3. Inten. illu.
*a*. dist. 1 : 2 : : illum. 1 : 4.
*b*. size of suns.

## GRAVITATION.

1st. law. masses. 2d. dists.
*a*. grav. on moon. *b*. sun.
*c*. near earth, far sun.
*d*. law of curv. motion.
*e*. of equipo.

## THE PLANETS.

1. Hang on o. 2. Names.
3. dists. 4. Rel. size.
5. speed. 6. ellipse.

## MERCURY.

1. Diam. 2. heat.

## VENUS.

1. Bright. 47°. 3. rain.
4. phases. 5. Appar. retrog.

## EARTH.

1. Dist. 2. Diam, Po, and equa. 3. eclipses. 4. meas. circum. 5. to sun. 6. burnt hand. 7. moon. 8. Dist. 9. diam. 10. motion. 11. surface. 12. path. 13. eclipses. 14. tides. 15. danger?

## MARS.

1. like earth. 2. so near, so far. 3. moons.

## JUPITER.

1. Dist. 2. Diam. 3. mass. 4. swift rota. 5. light meas. 6. self lu?

## SATURN.

1. Dist. 2. Diam. 3. mass. 4. Rings. 5. change. 6. moons.

## URANUS.

1. Dist. × Earth's.
2. moon's rev.

## NEPTUNE.

1. How found? 2. cold. 3. mnemo.

## COMETS.

1. var. dist. 2. speed. 3. aids de c. 4. Nos. 5. not dense. 6. meteors fr.

## METEORIC SYSTS.

1. wt. of. 2. Nos. 3. in streams. 4. 1831-2-3. 5. are invis. comets.

## FIXED STARS.

1. concen. circles. 2. Three base lines. 3. ° ′ ″. 4. near stars.

## DOUBLE STARS.

Pole. Mizar. Sirius. Near Vega. revolve, color.

## VARIABLE STARS.

Algol. Mira. Time.

## TRANSIENT STARS.

10 new—13 lost.

## SUN MOVES.

Toward Her. Star drift. Bind Alcyone?

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